Models for internal quality sorting of fruit, based on time-domain laser reflectance spectroscopy (TDRS)

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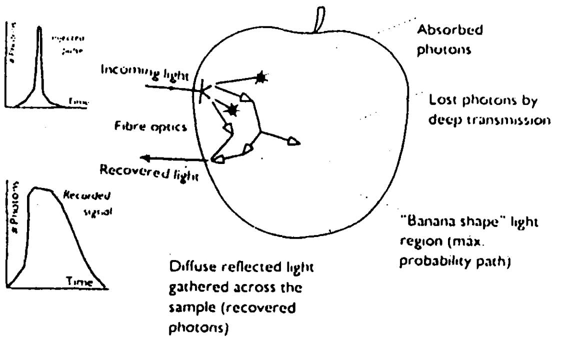
Purpose and procedures

Non-destructive measurement of fruit quality has been an important objective through recent years (Abbott, 1999). Near infrared spectroscopy (NIR) is applicable to the quantification of chemicals in foods and NIR "laser spectroscopy" can be used to estimate the firmness of fruits. However, the main limitation of current optical techniques that measure light transmission is that they do not account for the coupling between absorption and scattering inside the tissue, when quantifying the intensity of re-emitted light. The solution of this limitation was the goal of the present work.

Time domain laser reflectance spectroscopy (TDRS), developed for use in the field of medicine, has been applied for the first time in the evaluation of fruit internal quality or fresh food. It allows the simultaneous non-destructive measurement of two optical characteristics of the tissues: light scattering and absorption, obtaining information on their chemical composition and structure, using the same wavelengths. This technique (Cubeddu et al, 1999) measures the temporal broadening of a short light pulse transmitted through the fruit tissues. The light source is a pulsed laser. The recorded signal (instead of intensity as a function of wavelength as in traditional spectroscopy) is here a count of photons in time at each wavelength. Two variables are obtained per wl.: absorption coefficient (μ_a) and scattering coef. (μ'_s).



A database was created from TDRS measurements on 490 apples, 220 tomatoes, 200 peaches and 170 kiwifruits in VIS (λ at 672, 750 & 818nm) and NIR (λ from 900 to 1000nm, tuneable each 10nm), over a three-year period. Destructive measurements were carried out as references: skin puncture, Magness-Taylor penetration, quasi-static compression, skin VIS reflectance (%), titratable acidity and sugars (refractometer).

Data analysis consisted of a three step statistical process. First, Principal Component Analysis (PCA) and Multiple Stepwise Linear Regression (MSLR) were used to find relationships between the TDRS measurements and the references. Then Clustering was applied to "naturally group" fruits according to their quality: three scales (firmness, sugars and acids) were established dynamically with 3 classes each (high, medium, or low), and every sample was given 3 scores depending on its measured levels. Finally, models for independent estimation these 3 quality parameters were built with Discriminant Analysis (DA).

Results and discussion

With PCA, most of the firmness variables showed consistent correlation (>0.75) with TDRS scattering in the VIS region. The TDRS variables in the NIR region were well-correlated (>0.8) with taste attributes. DA models for firmness estimation (explained variables max force Magness-Taylor or puncture slope) were built using visible wavelegths (VIS λ), and models for sugars and acids using NIR data. The percentages of well-classified samples in three quality classes for each model are summarised in table 1, as well as the corresponding validations below.

Table 1. Summary of classification models (12) for non-destructive estimation of firmness, sugar content and acidity. For each quality parameter and fruit, the explained variable is indicated and number of TDRS wavelengths used

		Apple	*Peach*	*Kiwi*	*Tomato*
Models estimating firmness with VIS	Explained variable:	Max force Mg-Taylor	Max force Mg-Taylor	Puncture Slope	Puncture Slope
	Well classified samples:	76%	77%	75%	81%
	Validation:	74%	73%	75%	80%
	# Explicative wavelngths:	3 λ VIS	3 λ VIS	3 λ VIS	3 λ VIS
Models estimating sugar with NIR	Explained variable:	SST °brix	SST °brix	SST °brix	SST °brix
	Well classified samples:	77%	86%	75%	98%
	Validation:	71%	77%	62%	84%
	# Explicative wavelngths:	5 λ NIR	9 λ NIR	8 λ NIR	11 λ NIR
Models estimating acidity with NIR	Explained variable:	Acid meq/l	Acid meq/l	Acid meq/l	Acid meq/l
	Well classified samples:	74%	84%	70%	98%
	Validation:	72%	75%	66%	89%
	# Explicative wavelngths:	11 λ NIR	10 λ NIR	10 λ NIR	12 λ NIR

Conclusions

TDRS is applicable for the optical characterisation of the internal properties of fruits. Analysis of VIS and NIR data for apples, tomatoes, kiwifruits and peaches indicates that this technique can be used to predict firmness, soluble solids content and acidity. Results support the hypothesis that the scattering coefficient should relate to texture properties, while the absorption coefficient should be associated with chemical constituents. Further research is required to optimise the classification performance.

Abbott, J. A. 1999. Quality measurement of fruits and vegetables. *Postharvest Biology and Technology* 15, no. 3: 207-25.

Cubeddu, R., A. Pifferi, P. Taroni, G. Valentini, A. Torricelli, C. Valero, M. Ruiz-Altisent, and C. Ortiz. 1999. Non-destructive measurements of the optical properties of fruits by means of time-resolved reflectance. *International Biomedical Optics Symposium (BIOS).*